

IN THE CLAIMS:

1. (currently amended) A computer-implemented face recognition process for identifying a person depicted in an input image, comprising using a computer to perform the following process actions:

creating a database of a plurality of model image characterizations, each of which represents the face of a known person that it is desired to identify in the input image as well as the person's face pose;

~~comparing a region depicting the face of a person, which has been extracted from said input image and characterized in a manner similar to the plurality of model images, to the plurality of model image characterizations;~~

~~ascertaining which of the plurality of model image characterizations most closely matches the similarity characterized input image region; and~~

~~designating the input image region to be the person associated with the most closely matching model image characterization if a degree of similarity exceeds a prescribed threshold.~~

training a neural network ensemble to identify a person and their face pose from a region which has been extracted from said input image and characterized in a manner similar to the plurality of model images, wherein the network ensemble comprises, a first stage having a plurality of classifiers each of which has input and output units and is dedicated to a particular pose range and outputs a measure of the similarity indicative of the similarity between said characterized input image region and each of said model image characterizations associated with the particular pose range of the classifier, and a fusing neural network as its second stage which combines the outputs of the classifiers to generate an output indicative of the person associated with the characterized input image region; and

employing the network ensemble to identify the person associated with the characterized input image region.

2-4. (cancelled)

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5. (currently amended) The process of Claim 4~~1~~, wherein the process action for training the neural network ensemble comprises an action of preparing each model image characterization from a model image depicting the face of a known person that it is desired to identify in the input image by,

extracting the portion of the model image depicting said face,
normalizing the extracted portion of the model image by resizing it to a prescribed scale if not already at the prescribed scale and adjusting the region so that the eye locations of the depicted subject fall within a prescribed area, and

cropping the extracted portion of the model image by eliminating unneeded portions of the image not specifically depicting part of the face of the subject to create a model face image.

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6. (currently amended) The process of ~~Claim~~ Claim 5, wherein the process action for training the neural network ensemble further comprises actions for:

categorizing the model face images by assigning each to one of a set of pose ranges into which its associated face pose falls;

for each pose range,

choosing a prescribed number of the model face images of each person being modeled which have been assigned to the selected pose range,

concatenating each of the chosen model face images to create a respective dimensional column vector (DCV) for each,

computing a covariance matrix from the DCVs,

calculating eigenvectors and corresponding eigenvalues from the covariance matrix,

ranking the eigenvalues in descending order,

identifying a prescribed number of the top eigenvalues,

using the eigenvectors corresponding to the identified

eigenvalues to form the rows of a basis vector matrix (BVM) for the pose range;
and

multiplying each DCV by each BVM to produce a set of
principal components analysis (PCA) PCA coefficient vectors for each model
face image.

7. (currently amended) The process of Claim 6, wherein the ~~neural network ensemble employed comprises a plurality of face recognition neural networks each of which has input and output units and is dedicated to a particular pose range, said face recognition neural networks output units being in communication with input units of a~~ fusing neural network which has at least enough output units to allow a different output to represent each person it is desired to identify at each of the pose ranges, and wherein the process action of training the neural network ensemble further comprises the actions of:

for each face recognition neural network, inputting, one at a time, each of the PCA coefficient vectors associated with the pose range of the face recognition neural network into the inputs of the network until the outputs of the network stabilize;

initializing the fusing neural network for training;

for each DCV, simultaneously inputting the PCA coefficient vectors generated from the DCV into the respective face recognition neural network associated the vector's particular pose range group until all the PCA coefficient vectors of every DCV have been input, and repeating until the outputs of the fusing neural network stabilize; and

for each DCV, simultaneously inputting the PCA coefficient vectors generated from the DCV into the respective face recognition neural network associated the vector's particular pose range group and assigning the active output of the fusing neural network as corresponding to the particular person and pose associated with the model image used to create the set of PCA coefficient vectors.

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8. (currently amended) The process of Claim 7, wherein the process action of employing the neural network ensemble to identify the person depicted in the input image face region ~~and the pose associated with the face of the identified person~~, comprises the actions of:

preparing the face region extracted from an input image by normalizing and cropping the extracted regions, wherein said normalizing comprises resizing the extracted face region to the same prescribed scale if not already at the prescribed scale and adjusting the region so that the eye locations of the depicted subject fall within a prescribed area, and wherein the cropping comprises eliminated unneeded portions of the image not specifically depicting part of the face of the subject

concatenating the prepared face region to create a DCV;

multiplying the DCV by each BVM to produce a set of PCA coefficient vectors for the extracted face region;

inputting each PCA coefficient vector in the set of PCA coefficient vectors into the respective face recognition neural network associated that vector's particular pose range group; and

identifying the active unit of the output of the fusing neural network and designating the person and pose previously assigned to that unit as the person and pose associated with the extracted face region.

9. (currently amended) The process of Claim 3 1, ~~wherein the further comprising process actions for designating the input image region to be an unknown person comprises the actions of:~~

training the neural network ensemble to identify the person associated with the characterized input image region to be an unknown person if it does not match any of the model image characterization to a prescribed degree; and

employing the neural network ensemble to identify the person associated with the characterized input image region to be an unknown person if it does not match any of the model image characterization to the prescribed

degree.

10. (currently amended) A face recognition system for identifying a person depicted in an input image, comprising:

a general purpose computing device; and

a computer program comprising program modules executable by the computing device, wherein the computing device is directed by the program modules of the computer program to,

capture model images, each of which depicts at least one person of known identity,

locate and extract regions within the model images, each of which depicts the face of a known person that it is desired to identify in the input image,

determine the face pose for each of the face regions extracted from the model images,

categorize each face region by assigning each to one of a set of pose ranges into which its associated face pose falls,

~~capture said input image,~~

~~locate and extract regions within the input images, each of which depicts the face of a person, and~~

~~for each face region extracted from the input image, comparing the face region to the face regions assigned to each pose range to identify the person depicted in the input image face region.~~

train a neural network ensemble to identify a person and their face pose from a region that depicts the face of a person which has been extracted from said input image, wherein the network ensemble comprises, a first stage having a plurality of classifiers each of which has input and output units and is dedicated to a particular pose range and outputs a measure of the similarity indicative of the similarity between said input image region and each of said model image regions associated with the particular pose range of the classifier, and a fusing neural network as its second stage which combines the

outputs of the classifiers to generate an output indicative of the person associated with the characterized input image region; and
employing the network ensemble to identify the person associated with the characterized input image region and their face pose.

11-14. (cancelled)

5207 15. (currently amended) The system of Claim 44-10, wherein the sub-module for training the neural network ensemble comprises a sub-module for preparing each face region extracted from said model images by normalizing and cropping the extracted regions, wherein said normalizing comprises resizing each extracted face region to the same prescribed scale if not already at the prescribed scale and adjusting each region so that the eye locations of the depicted subject fall within the same prescribed area, and wherein said cropping comprises eliminating unneeded portions of the image not specifically depicting part of the face of the subject.

16. (currently amended) The system of Claim 15, wherein the sub-module for training the neural network ensemble further comprises sub-modules for:

- (a) selecting a previously unselected one of the set of pose ranges;
- (b) choosing a prescribed number of the prepared face images of each person being modeled which have been assigned to the selected pose range;
- (c) concatenating each of the chosen prepared face images to create a respective dimensional column vector (DCV) for each;
- (d) computing a covariance matrix from the DCVs;
- (e) calculating eigenvectors and corresponding eigenvalues from the covariance matrix;
- (f) ranking the eigenvalues in descending order;

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- (g) identifying a prescribed number of the top eigenvalues;
 - (h) using the eigenvectors corresponding to the identified eigenvalues to form the rows of a basis vector matrix (BVM) for the selected pose range;
 - (i) repeating actions (a) through (h) for each remaining pose range;
 - (j) multiplying each DCV by each BVM to produce a set of principal components analysis (PCA) PCA coefficient vectors for each face image.

17. (currently amended) The system of Claim 16, wherein the ~~neural network ensemble employed comprises a plurality of face recognition neural networks each of which has input and output units and is dedicated to a particular pose range, said face recognition neural networks output units being in communication with input units of a fusing neural network which has at least enough output units to allow a different output to represent each person it is desired to identify at each of the pose ranges, and wherein the sub-module for training the neural network ensemble further comprises sub-modules for:~~

for each face recognition neural network, inputting, one at a time, each of the PCA coefficient vectors associated with the pose range of the face recognition neural network into the inputs of the network until the outputs of the network stabilize;

initializing the fusing neural network for training;

for each DCV, simultaneously inputting the PCA coefficient vectors generated from the DCV into the respective face recognition neural network associated the vector's particular pose range group until all the PCA coefficient vectors of every DCV have been input, and repeating until the outputs of the fusing neural network stabilize; and

for each DCV, simultaneously inputting the PCA coefficient vectors generated from the DCV into the respective face recognition neural network associated the vector's particular pose range group and assigning the active

output of the fusing neural network as corresponding to the particular person and pose associated with the model image used to create the set of PCA coefficient vectors.

18. (original) The system of Claim 17, wherein the sub-module for employing the neural network ensemble to identify the person depicted in the input image face region and the pose associated with the face of the identified person, comprises sub-modules for:

preparing the face region extracted from an input image by normalizing and cropping the extracted regions, wherein said normalizing comprises resizing the extracted face region to the same prescribed scale if not already at the prescribed scale and adjusting the region so that the eye locations of the depicted subject fall within a prescribed area, and wherein the cropping comprises eliminated unneeded portions of the image not specifically depicting part of the face of the subject;

concatenating the prepared face region to create a DCV;

multiplying the DCV by each BVM to produce a set of PCA coefficient vectors for the extracted face region;

inputting each PCA coefficient vector in the set of PCA coefficient vectors into the respective face recognition neural network associated that vector's particular pose range group; and

identifying the active unit of the output of the fusing neural network and designating the person and pose previously assigned to that unit as the person and pose associated with the extracted face region.

19. (currently amended) The system of Claim 10, wherein the program module for designating the face region extracted from the input image to be an unknown person comprises further comprising sub-modules for:

training a the neural network ensemble to identify the person associated with the input image face region to be an unknown person if it does not match any of the face regions assigned to each pose range to a prescribed

degree; and

employing the neural network ensemble to identify the person associated with the input image face region to be an unknown person if it does not match any of the face regions assigned to each pose range to a prescribed degree.

20. (currently amended) A computer-readable memory for use in identifying a person depicted in an input image, comprising:

a computer-readable storage medium; and

a computer program comprising program modules stored in the storage medium, wherein the storage medium is so configured by the computer program that it causes a computer to,

input model images, each of which depicts at least one person of known identity,

locate and extract regions within the model images, each of which depicts the face of a known person that it is desired to identify in the input image,

determine the face pose for each of the face regions extracted from the model images,

categorize each face region by assigning each to one of a set of pose ranges into which its associated face pose falls,

~~capture said input image,~~

~~locate and extract regions within the input images, each of which depicts the face of a person, and~~

~~for each face region extracted from the input image, comparing the face region to the face regions assigned to each pose range to identify the person depicted in the input image face region.~~

train a neural network ensemble to identify a person and their face pose from a region depicting the face of a person which has been extracted from said input image, wherein the network ensemble comprises, a first stage having a plurality of classifiers each of which has input and output units

and is dedicated to a particular pose range and outputs a measure of the similarity indicative of the similarity between said input image region and each of said model image regions associated with the particular pose range of the classifier, and a fusing neural network as its second stage which combines the outputs of the classifiers to generate an output indicative of the person associated with the characterized input image region; and
employing the network ensemble to identify the person associated with the characterized input image region and their face pose.

21-24. (cancelled)

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25. (currently amended) The computer-readable memory of Claim 24 20, wherein the sub-module for training the neural network ensemble comprises a sub-module for preparing each face region extracted from said model images by normalizing and cropping the extracted regions, wherein said normalizing comprises resizing each extracted face region to the same prescribed scale if not already at the prescribed scale and adjusting each region so that the eye locations of the depicted subject fall within the same prescribed area, and wherein said cropping comprises eliminating unneeded portions of the image not specifically depicting part of the face of the subject.

26. (currently amended) The computer-readable memory of Claim 25, wherein the sub-module for training the neural network ensemble further comprises sub-modules for:

- (a) selecting a previously unselected one of the set of pose ranges;
- (b) choosing a prescribed number of the prepared face images of each person being modeled which have been assigned to the selected pose range;
- (c) concatenating each of the chosen prepared face images to create a respective dimensional column vector (DCV) for each;

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- (d) computing a covariance matrix from the DCVs;
 - (e) calculating eigenvectors and corresponding eigenvalues from the covariance matrix;
 - (f) ranking the eigenvalues in descending order;
 - (g) identifying a prescribed number of the top eigenvalues;
 - (h) using the eigenvectors corresponding to the identified eigenvalues to form the rows of a basis vector matrix (BVM) for the selected pose range;
 - (i) repeating actions (a) through (h) for each remaining pose range.
 - (j) multiplying each DCV by each BVM to produce a set of principal components analysis (PCA) PCA coefficient vectors for each face image.

27. (currently amended) The computer-readable memory of Claim 26, wherein the ~~neural network ensemble employed comprises a plurality of face recognition neural networks each of which has input and output units and is dedicated to a particular pose range, said face recognition neural networks output units being in communication with input units of a fusing neural network which has at least enough output units to allow a different output to represent each person it is desired to identify at each of the pose ranges, and wherein the sub-module for training the neural network ensemble further comprises sub-modules for:~~

for each face recognition neural network, inputting, one at a time, each of the PCA coefficient vectors associated with the pose range of the face recognition neural network into the inputs of the network until the outputs of the network stabilize;

initializing the fusing neural network for training;

for each DCV, simultaneously inputting the PCA coefficient vectors generated from the DCV into the respective face recognition neural network associated the vector's particular pose range group until all the PCA coefficient

vectors of every DCV have been input, and repeating until the outputs of the fusing neural network stabilize; and

for each DCV, simultaneously inputting the PCA coefficient vectors generated from the DCV into the respective face recognition neural network associated the vector's particular pose range group and assigning the active output of the fusing neural network as corresponding to the particular person and pose associated with the model image used to create the set of PCA coefficient vectors.

92 28. (original) The computer-readable memory of Claim 27, wherein the sub-module for employing the neural network ensemble to identify the person depicted in the input image face region and the pose associated with the face of the identified person, comprises sub-modules for:

preparing the face region extracted from an input image by normalizing and cropping the extracted regions, wherein said normalizing comprises resizing the extracted face region to the same prescribed scale if not already at the prescribed scale and adjusting the region so that the eye locations of the depicted subject fall within a prescribed area, and wherein the cropping comprises eliminated unneeded portions of the image not specifically depicting part of the face of the subject;

concatenating the prepared face region to create a DCV;

multiplying the DCV by each BVM to produce a set of PCA coefficient vectors for the extracted face region;

inputting each PCA coefficient vector in the set of PCA coefficient vectors into the respective face recognition neural network associated that vector's particular pose range group; and

identifying the active unit of the output of the fusing neural network and designating the person and pose previously assigned to that unit as the person and pose associated with the extracted face region.

29. (currently amended) The computer-readable memory of Claim 23

~~20, wherein the program module for designating the face region extracted from the input image to be an unknown person comprises further comprising sub-modules for:~~

~~training a neural network ensemble to identify the person associated with the input image face region to be an unknown person if it does not match any of the face regions assigned to each pose range to a prescribed degree; and~~

~~employing the neural network ensemble to identify the person associated with the input image face region to be an unknown person if it does not match any of the face regions assigned to each pose range to a prescribed degree.~~

30. (cancelled)

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extracting the portion of each model image depicting a face;

normalizing the extracted portion of each model image by resizing it to a prescribed scale if not already at the prescribed scale and adjusting the region so that the eye locations of the depicted subject fall within a prescribed area;

cropping the extracted portion of each model image by eliminating unneeded portions of the image not specifically depicting part of the face of the subject to create a model face image;

concatenating each of the model face images to create a respective model dimensional column vector (DCV) for each,

categorizing the model ~~DCVs~~ DCVs by assigning each to one of a set of pose ranges into which its associated face pose falls;

inputting the model ~~DVG~~ DCV of the each model face image falling in a particular pose range, one at a time, to a pre-selected classifier dedicated to the particular pose range.

32. (currently amended) The process of Claim 31, wherein the process action of training the network ensemble further comprises the actions of:

initializing the fusing neural network for training;

simultaneously inputting the respective ~~DVG~~ DCV of each model face image into all classifiers, until the ~~DVG~~ DCV of every model image has been input, and repeating until the outputs of the neural network stabilize; and

simultaneously inputting the respective ~~DVG~~ DCV of each model face image into all classifiers, and assigning the active output the neural network as corresponding to the particular person and pose associated with the model image used to create the DCV.

33. (currently amended) The process of Claim 32, wherein the process action of employing the network ensemble to identify the person depicted in the input image face region, comprises the actions of:

preparing the face region extracted from an input image by normalizing and cropping the extracted regions, wherein said normalizing comprises resizing the extracted face region to the same prescribed scale if not already at the prescribed scale and adjusting the region so that the eye locations of the depicted subject fall within a prescribed area, and wherein the cropping comprises eliminated unneeded portions of the image not specifically depicting part of the face of the subject;

concatenating the prepared face region to create a DCV;

inputting the ~~DVG~~ DCV of the face region into all classifiers; and

identifying the active output of the neural network and designating the person previously assigned to that unit as the person associated with the extracted face region.

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34. (original) The process of Claim 33, further comprising a process
action of specifying that the person designated as associated with the extracted
face region has the face pose previously assigned to the identified active output.

35-42. (withdrawn)